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CONTROL OF SALINITY FROM BOTH POINT SOURCES YIELDING GROUNDWATER DISCHARGE, AND DIFFUSE SURFACE RUNOFF

1978 STATUS REPORT

June, 1979

U.S.D.I., BUREAU OF LAND MANAGEMENT
DENVER SERVICE CENTER
OFFICE OF TECHNICAL AND SCIENTIFIC SERVICES
DIVISION OF SPECIAL STUDIES
COLORADO RIVER SALINITY STUDY

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I. INTRODUCTION

The Bureau of Land Management (BLM) has recently completed a two-year study of salinity from diffuse overland runoff (BLM, 1978). This work was completed in response to an October 30, 1973, memo from the Assistant Secretary of Land and Water Resources, U.S. Department of the Interior, jointly to BLM and the Bureau of Reclamation (BR). The memo instructed the two Bureaus to work together on the salinity problem in the Colorado River Basin, and BLM to begin active study of possible means of controlling salt movement into the Colorado River. The Colorado River Basin Salinity Control Act, P.L. 93-320, also requires interagency coordination in solving the salinity problem of the Colorado River.

A. During Fiscal Year 1978, the Bureau's salinity study team continued investigations into the causes of salinity from public lands. This work included an analysis of factors causing salinity of groundwater, as well as a continuing study of salinity from surface runoff. The goals of the groundwater phase of the salinity study are:

1. To assess the salt contribution from groundwater throughout a vast area within the Upper Basin. This includes collection and analysis of data from key locations, not previously investigated. Also to analyze this and existing data, to obtain a more complete picture of the quanity and quality of groundwater. Finally, to relate groundwater data to geologic formations and other site conditions. This work as been contracted to the Geological Survey (GS).

2. To investigate specific saline groundwater point discharges, and to monitor quantity and quality of water and yearly variations. Also

to study the technical and economic feasibility of controlling such saline discharges.

The important aspects of each type of point source, e.g., flowing well, spring, and saline groundwater interface are discussed.

B. The salinity team has continued to study causes and means of control of salinity from surface runoff. The goal is to:

1. Incorporate new research findings into salinity control procedures and further test the validity of existing techniques.

II. INVESTIGATIONS

A. Groundwater

The GS has conducted groundwater investigations for BLM in Wyoming and Colorado. Water quantity and quality measurements were made at strategic points along perennial stream channels and at springs. Measurement locations coincide with contacts between geologic formations, where soils or vegetative changes occur, and at confluences of streams. Data is being analyzed to determine locations of water and salt inflow into perennial streams. This is an attempt to understand the conditions relating to induction of saline groundwater into surface waters. Saline groundwater may travel along geologic contacts, faults, through porous or fractured formations, gravel deposits, or porous soils (sands). Obvious changes in rock alignment, structure, color, escarpments, changes in soil texture and vegetation community boundaries may possibly be clues to points of saline inflow.

The data collection and analysis phases were completed in early September, 1978. A report of findings will be completed in draft form by summer, 1979. It will undergo a series of reviews and revisions before being submitted to BLM. A draft of the final product may be available for use by technical personnel by early 1980 fiscal year. The report may not appear in published form for another year.

The important point source emissions of groundwater are listed below with an explanation of possible factors affecting their surface discharge.

flowing well, bore hole -- man caused saline groundwater discharge by artesian pressure.

artesian spring -- natural discharge of saline groundwater under pressure.

spring, seep -- point source saline discharge by gravity along a fault or outcrop of porous material.

effluent stream or groundwater interface -- gravity discharge of saline groundwater along a fault or porous material ending in the bed of a stream. This may be either a point or diffuse source emission.

saline geologic outcrop in the bed of a stream -- salt pickup as perennial or ephemeral water flows over the outcrop.

Saline springs and seeps allow examination of saline aquifers through a surface discharge. Such discharge points are easier to locate and may be easier to control than inflow directly into channels. Possible control measures are evaporation ponds, deep well injection, and plugging. Evaporation requires a means of collecting all discharge, a transportation system, and a suitable disposable site.

The collector system can be relatively simple where a spring discharges from one point, or may be more elaborate where discharge is emitted from a diffuse area. The major concern in designing the collector system is that it completely intercept saline waters, thus preventing salt from entering perennial stream flow and/or storm runoff. Care should be taken to minimize the inflow of non-saline surface flows into the collector. A large volume of runoff water entering the system could cause saline spills, or rupture of the collector dike, the transportation system, or disposal component. The collector may consist of a dike across a channel to collector dike should be deep enough to be anchored to an impervious layer (bedrock, tight clay). This is especially important for diversion dikes intersecting subsurface saline channel flow.

The conveyance system transports saline water from the source (collector) to the disposal site. It can take the form of an open channel (ditch) or a closed pipeline. A lined, open channel can function well where it can be designed for gravity flow and drainage channels can be crossed without too much difficulty. However, a closed pipeline is generally preferred. Chances for failure of the system are reduced and greater protection

is afforded to the surrounding environment. If the evaporation site is located at an elevation higher than the collector, a pump and pipeline would be required.

The disposal site (evaporation pond(s), deep well injection) should be located as close as possible to the salt source. Evaporation ponds are a preferred means of disposal if a relatively level plot of land of sufficient size is available nearly. Deep well injection requires a power source and could possibly result in damaging environmental side effects (leakage into freshwater aquifers, pressure caused earthquake). An evaporation pond system should have a storage capacity sufficient to hold the annual saline spring discharge, less evaporation, plus annual precipitation (rain, snow), plus volume of accumulating salt over the life of the project. A series of evaporation ponds is desirable, if sufficient level ground is available. Accumulated salts from evaporation will be concentrated in the last pond of the series. The other ponds would have decreasing salt concentrations, progressing from the last pond back toward the source, with the first pond having a salinity only slightly greater than the saline source. The ponds first in the chain could potentially provide habitat for waterfowl. The ponds with the highest salt concentrations could be hazardous to waterfowl.

Dikes creating evaporation ponds would be high enough to afford protection against overflow resulting from wave action, and provide storage of abnormally high rainfall. The dike system should also keep overland storm runoff from entering the evaporation ponds. Cost of pond construction

will be less when ponds are located on fine-textured soils. The bottom and sides of ponds must be sealed to eliminate seepage. Materials suitable for lining ponds are fine-textured soil (clay), bentonite, and man-made products (plastic, nylon, or butyl rubber sheets). The size of ponds may be reduced by the installation of an aeration system. However, this requires a power source, greater maintenance, and increased operational costs. Preliminary studies by BR indicate that evaporation rates are highly variable and are significantly reduced as concentration of salts approach brine conditions. This could affect the size of ponds needed or even the viability of the use of evaporation ponds for salinity control.

The deep well injection disposal process is only possible where geologic formations are porous enough to accept brine and yet not fractured to the extent that brine would escape to contaminate fresh water aquifers. This process is currently being used by oil and gas companies as a means of disposing of saline water, a byproduct of oil production. However, deep well injection is a costly process. It requires an adequate supply of power to pump brine under pressures sometimes up to 3,000 pounds per square inch (psi).

Surface flow can take salts into solution when water comes in contact with exposed saline geologic formations. Pickup of salts can be halted by eliminating the surface water - saline rock contact zone. This can be accomplished by constructing a barrier dam - diversion dike, anchored to impervious substrata, across the channel upstream from the saline

outcropping formation. The top of the dike should be low enough to allow high storm flow to pass over the dam without damage to the transport system. The dike would divert normal channel flow into a parallel transport channel, i.e., a concrete lined ditch or pipeline. The transport system would traverse the entire length of the exposed saline formation and then end where channel flow can be dumped back into the natural channel on a non-saline formation.

Abandoned oil and gas exploration wells may penetrate a number of fresh water and saline aquifers, some at several thousand feet below the surface. If these are under artesian pressure, mixing of water can occur between aquifers, causing contamination of fresh water. Artesian pressures can also force saline water to the surface, discharging over the land, with a potential for contaminating surface streams. Water from deep formations can be extremely saline, with concentration of salts of 10,000 or more milligrams per litter (mg/l). Surface contamination from saline aquifers can be eliminated by plugging above and below the producing geologic formation. If the well cannot be successfully plugged, the saline water can be collected on the surface and disposed of in a manner similar to discharge from a spring.

B. Surface Water

Grazing by herbivores (domestic, feral, and wildlife) is considered to be a significant factor in causing increases of salinity in overland or surface runoff from wildlands. Grazing, especially by domestic livestock, is the most extensive man-caused use of these lands, both federally managed,

and state and privately controlled. Heavy grazing results in loss of protective vegetation, compaction of soils, reductions of infiltration, increased runoff, and increased erosion. Meehan and Platts ( ) state that management of rangelands is closely interelated with water management. "The combined effects of geology, climate, geomorphology, soil, vegetation, and water runoff often result in unstable stream conditions in the natural state. When land uses place additional stress on aquatic habitats, damage usually occurs." Water management and maintenance of stable stream channels are closely interrelated to control of salinity from diffuse surface runoff.

The Council for Agricultural Science and Technology ( ) report that the degree to which grazing enhances other resources depends on the kind of range, objectives of grazing management, and skill of range managers. In order to be effective, ".....grazing must be scientifically controlled and responsive to the needs of all users." Management of all kinds of grazing animals can be an effective salinity control practice. This management may include total or temporary exclusion of livestock (BLM, Gunderson, Hughes, Johnson, Meehan and Platts, and Turcott). Lieurance ( ) suggests that long-term stability of ranges cannot be achieved if they are overstocked. Adjustments will continue to be necessary in the future, in order to protect the resources. However, reducing livestock numbers alone is not the answer; systematic grazing management is also required.

The BLM administers about 150 million acres of grazing lands in the western United States (Comptroller General of the United States, Lieurance).

Of this, 135 million acres are producing livestock forage below their potential. The Comptroller General reported that Allotment Management Plans, outlining systematic grazing schedules, did not exist for 107 million acres of public lands ( ). Land deterioration was principally attributed to "poorly managed livestock grazing." The report cited a 1976 address by the BLM Director to a group of Nevada public land users, in which he stated that unauthorized grazing by numbers of livestock in excess of those allowed by BLM ".....was the largest contributor to the state's deteriorated rangelands."

A continued search of the literature shows a predominance of study results indicating that grazing at all levels affects soil compaction, with a corresponding reduction of infiltration and increase of runoff. Rauzi and Hanson (1966) found a nearly linear relationship existed between grazing intensity and rate of water intake. Smeins (1975) and Johnson (1978) both state that grazing management practices designed to increase livestock production also have a definite impact on the interrelationships of soil, vegetation, and hydrologic processes. The degree of influence upon hydrologic responses is related to intensity of grazing, and the harmful effects of grazing are greatly reduced by light and moderate grazing. Knoll and Hopkins (1959), Rauzi (1963), and Rhoades et al (1964) found significant differences in infiltration rates between nongrazed and lightly or moderately grazed areas.

Not so:
This is
only true
under
continuous
grazing

Johnston (1962), Rauzi (1963), and Rhoades et al (1964) found significant differences in water intake rates on areas grazed at rates between light,

moderate and heavy intensity for periods of more than 20 years. Hanson et al (1970) found after 26 years, areas grazed heavily yielded significantly more runoff than those grazed moderately, and moderate grazing yielded significantly more runoff than from areas grazed only lightly. McCarty and Mazurak (1976) reported significant increases in soil bulk density and decreases in total soil porosity on areas grazed at heavy-continuous and moderate-deferred-rotation rates over nongrazed areas, after 25 years of treatment. Rauzi et al (1968) conducted water intake studies for several years on rangelands in the mixed and tall prairies in six Northern and Central Plains States. It was found that both live vegetation and litter were highly correlated with water intake rate. Soil structure was the most important soil influence on infiltration and was second in importance after vegetation. Soil factors were more important in affecting rate of water intake than vegetative factors on salinealkali upland range sites. McGinty et al (1979) found soil characteristics accounted for the greatest proportion of variation in infiltration on shallows soils with low plant cover.

Rauzi et al (1968) report that unfavorable soil conditions greatly reduced water intake rates, even where vegetative cover was good. Infiltration can be reduced, even on a normally highly permeable sandy range when poor soil structure (aggregation of soil particles) is developed by forces causing compaction, such as excessive livestock trampling. It was reported that trampling caused increased bulk density and loss of pore space, destroyed vegetation and increased percent of

bare ground, and caused sealing of the surface pores with fine soil particles through raindrop splash erosion. Rauzi and Hanson (1966) reported data indicating heavy grazing had altered soil structure. Rauzi and Zingg (1956) compared water intake data from many sites within the Great Plains, representing a variety of soils and climate, but with comparable condition of vegetative cover. It was found that intake rates were relatively correlated with surface texture of soils, increasing with coarsness of soil particles. Tromble et al (1974) found that surface rock or gravel significantly reduced infiltration.

Johnston (1962) found the rate of water intake increased with increasing amounts of standing vegetation and natural mulch (litter). Rauzi (1963) and Rauzi and Hanson (1966) reported total herbage and mulch accounted for 88 percent and 71 percent of the variation in infiltration rate, respectively. Tromble et al (1974) also found that litter and crown cover were highly correlated with increased infiltration. Basal area of plants was not a significant factor. Lusby (1979) reported apparent reductions of about 75 percent in runoff and about 80 percent in sediment, by converting sagebrush sites to grass. The establishment of grass resulted in a reduction of 38 percent in the amount of bare soil. However, at the same time, the control (sagebrush) watersheds, which were ungrazed during the 9 year study, showed an 8 percent decrease in bare soil and a 27 percent reduction in sediment concentration.

Rauzi and Hanson (1966) found a significant relationship between species

composition of grasses and grazing intensity. This work was later supported by Hanson et al (1970). Heavy and moderate grazing resulted in a deterioration of vegetation from midgrasses to short grasses and sedges. Measurements recorded 97 and 80 percent composition of blue grama and buffalograss (short grasses) on the heavy and moderate grazing areas, respectively. Midgrasses (predominantly western wheatgrass) were maintained on the lightly grazed area.

Costello and Turner (1941) during a study of more than 100 exclosures, found that recovery of perennial vegetation (especially shrubs) was very slow under natural conditions. Exclosures over 30 years old showed the greatest percentages of the highly palatable plants. Willard and Herman (1977) report that improvement in range condition is slow on the Northern Great Plains, even under grazing management. Greater improvement in soil and plant conditions was observed from winter grazing than rest-rotation. This was attributed to frozen soils, reducing the ability of livestock trampling to compact soils. Laycock (1967), using species composition and plant vigor as indicies of change, found desert ranges in poor condition improved when grazed only in the fall, while those in good condition deteriorated under spring grazing. Cook (1971) found 60 percent utilization of cold desert plants during winter was too severe to maintain plants in good vigor. The rate of recovery of plants from defoliation was proportional to the initial state of plant vigor. Plants grazed when in low vigor were slower to recover under complete rest. It was suggested that 50 percent utilization would maintain optimum vigor and sustained yield.

not so —
On the
3 pasture
rest rotation
In 8 yrs
it was in
good
condition

Buwai and Trlica (1977) and Trlica et al (1977) conducted defoliation studies on a semiarid northwestern Colorado rangeland. These data indicate the effects of defoliation on plant health depend upon the species of plant, stage of growth (phenology), and the number of defoliations. A number of plants produced smaller herbage yields and showed reduced vigor following multiple defoliations at a moderate level. They were most severely affected by heavy defoliations. A number of plants recovered within 14 to 26 months after a single heavy defoliation. Plants clipped when green or during the rapid growth stage did not make complete recovery following the rest period. Cook and Childs (1971) state that plant vigor may have also been affected by the harsh conditions of the desert site. The warning was given that desert ranges in the Intermountain area are in a delicate natural balance and can deteriorate rapidly if not used correctly.

Martin (1973) reported on data believed to support "... the view that little benefit is gained by resting the range for only part of a normal grazing period." It was suggested that a grazing schedule for semidesert ranges in Arizona should provide rest during 2 out of 3 years when plants are growing. It was also stated that a grazing system be designed to remove 40 percent of the perennial grass production. Smeins (1975) believes that periodic, shortterm, and partial defoliation of plants may have beneficial effects on hydrologic processes, as well as vegetation. It was stated that a favorable forage resource may be maintained, erosion hazard not increased, and good quality runoff water

Stocking to 40% of total allotment gives 66% ungrazed areas

possibly increased. M^{c}Ginty et al (1979) found no significant differences in infiltration rate between a 4-pasture grazing system and a long-time exclosure.

Lusby (1978) reported on data collected during two distinct study periods at Badger Wash, Colorado. In the first period (1953-65) heavy grazing by sheep and cattle occured during the winter and spring (November 15 to May 15). Grazing in the second period (1966-73) was at a moderate level by sheep during the winter (November 15 to February 15). Rate of runoff and sediment loss were used as indicators of site stability. The report concludes that moderate grazing during winter is not significantly more harmful than nongrazing. Heavy grazing and grazing during spring when soil is moist are definitely detrimental. Discussion with Lusby (1979a) revealed that overall, moderate winter grazing produced 10 percent more sediment loss than nongrazing.

Recent investigations in arid and semiarid regions of western Colorado, on the contribution of interflow to salinity of groundwater, found that recharge did not come from precipitation falling on large areas of rangeland ( ). Evidence from both sites indicated that the direction of net water movement was upward rather than downward. M^{c}Whorter and Skogerboe (1979) theorized recharge occured when runoff or snowmelt on the upper borders of the watershed intersected exposed bedrock. Data from a series of observation wells showed that groundwater moved along a contact between bedrock and the soil profile. Salinity profiles in the weathered materials suggested these were not an avenue for recharge.

III. POSSIBLE SALINITY CONTROL PROJECTS FOR POINT SOURCE GROUNDWATER DISCHARGES

A. Flowing Well

An exploratory oil well was drilled along Bitter Creek, just east of Rock Springs, Wyoming in 1937. The well is located in the SW1/4SW1/4 of section 18, T.19N., R.103W., 6th Principal Meredian. It was drilled to a depth of 4,546 below ground surface, but no oil was found. The hole was apparently cased to a depth of 3,494 feet, with a smaller steel liner extended to 4,546 feet. The liner was perforated at several depths, see Figure 1. A saline water bearing zone under artesian pressure is located in the Sundance Formation. The well originally discharged about 700 gallons of water per minute (gPM), but it was estimated to be releasing only 50 gpm in the summer of 1978, see Figure 2. In 1978 concentration of total dissolved solids (TDS) was measured at 9,600 mg/1.

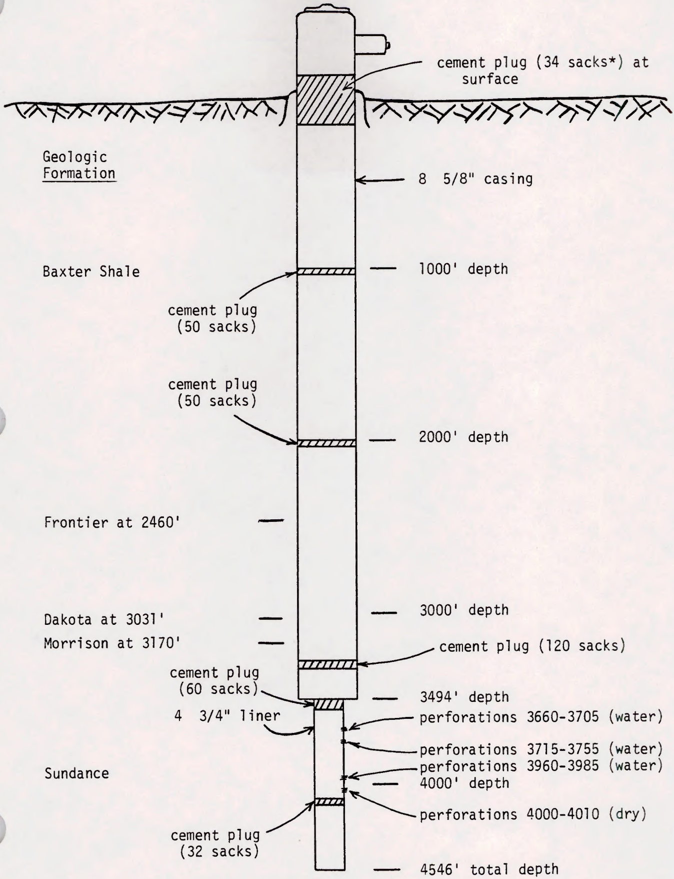
The well was closed successfully with a cement plug at a depth of 3,474 feet in 1939. In 1963, it was reopened and the water used in the construction of Interstate Highway 80. Sometime thereafter, it was again plugged by pumping cement from the surface downward into the casing to a depth of 1,036 feet. The saline flow was stopped for a time, until the casing rotted away, and water began flowing around the cement plug onto the surface at a rate of 50 gpm.

On September 22, 1978 preparations were begun to clean out the well and plug it a third time. A five inch diameter hole was drilled through the 1,036 foot cement plug on October 3. Little evidence was found of the casing, however, the top of the liner was touched on October 4. An expandable packing device was positioned at 4,119 feet and mud pumped into the entire well column. It was reported that the flow of water was stopped on October 5. A series of six cement plugs were set in the well, at varying depths, during October 6 and 7, see Figure 1.

The costs to plug the well are as follows:

BLM Supervision	$ 2,600
BLM and contract site preparation (gravel access road, level drill site, clean up site)	4,700
Drilling and Plugging Contract.	$35,400
Total	$42,700

Figure 1. Available information about well, its development and plugging.



*Note: One sack = 1.1 cubic feet

Figure 2. Area around the well head showing flow and accumulated deposits, June, 1978.

A flow of water at 50 gpm, with a concentration of 9,600 mg/l, would yield a total of 1,044 tons of salt and 80 acre-feet (ac-ft) of water annually. The annual cost of a one mg/l rise in salinity at Imperial Dam, California was computed to be $330,800 in 1977, see BLM, 1978. BR currently uses $343,000 ( ). The value of $330,800 will be used in this report, in order to be compatible with revisions in the grazing treatments section.

Plugging of the well, totally stopping the saline flow, resulted in a reduction of salinity at Imperial Dam of 0.073 mg/l. The annual value of this benefit would be $24,140. The reduction in salinity is the sum of the positive effects of removing 1,044 tons of salt and the negative effects of removing 80 ac-ft of water, annually.

The benefit-cost (B/C) ratio was computed using the following information.

Assume:

$330,800 cost of 1 mg/l rise in salinity at Imperial Dam.

14.02 buildup factor for FY 1979 to compute present value of benefits, using a 6.875 percent discount rate.

0.073 mg/l benefit from plugging well.

Present Value of Costs (PVC)

$42,700 = one-time cost to plug saline flowing well.

Present Value of Benefits (PVB)

PVB = 0.073 mg/l x $330,800 x 14.02 = $338,561

Benefit/Cost Ratio

$$B/C = \frac{PVB}{PVC} = \frac{\$338,561}{42,700} = 7.93:1$$

Net Project Benefits

	PVB:	$338,561
less	PVC:	$ 42,700
		$295,861

This data would indicate that nearly $340,000 could have been spent to plug the well before the enterprise would have ceased to be economical. Before attempting to plug an old abandoned oil well flowing under artesian pressure, it should be recognized that a number of potential problems can be encountered. A successful operation depends upon a knowledge of the stratigraphic column (position and order of sequence of geologic strata) from the bottom of the well to the surface. This would include information on lithology (structure, mineral composition, color and texture of rock formations), porosity, and permeability. The depths and intervals of aquifers must be known, as well as the identification of those under a hydraulic head (artesian). The date the well was drilled and cased, the type of casing used (including diameter and material), total depth of casing, and depth and interval of perforations or screens must be known. Such information can be obtained from a detailed driller's log (Campbell and Lehr, 1973). An analysis of chemical constituents in the water (corrosive properties) will give a clue to the present condition of the casing (BR, 1977).

The structure and mineral composition of rock units will affect whether the walls of the hole are stable or may have caved in or will cave in during plugging operations. Cement plugs may not effectively seal off aquifers if the casing has rotted away or if the walls of the hole are not stable. If the condition of the well is very poor, a new hole may need to be drilled along side it. This can greatly increase costs. Drilling out an existing cased hole can be expensive if rotted casing, sluffing of the walls of the hole, or other detrimental conditions cause equipment to be lost in the hole during drilling. Problems can also occur if grouting is not used, or is improperly done, allowing saline water under artesian pressure to flow around the casing or outside the well bore via fractures, and reach the surface or contaminate other aquifers. The Ground Water Manual (BR, 1977) gives a good explanation of how a cement-based grout between the soil walls of the bore and the casing, can not only seal a well but serve as a concrete casing if the casing is lost through corrosion.

B. Diffuse Point Discharge Springs

1. Salt Creek Spring

Salt Creek drains Sinbad Valley and is tributary to the Dolores River. The mouth of Salt Creek is located nine miles south of Gateway, Colorado. Base flow is furnished by several small springs at or near the mouth of Sinbad Valley. High flow comes from snowmelt and rainfall runoff. Surface flow in Salt Creek is ephemeral, drying up in the hot summer months. However, subsurface flow is perennial. Discharge from the saline springs at the mouth of Sinbad Valley is perennial, yielding approximately 100 gpm or

160 ac-ft per year. Concentration of salts in this water is 61,200 mg/l, resulting in a total salt yeild of 13,317 tons annually. If the flow from these springs could be controlled, kept from entering the Dolores River, this action would result in a reduction of salt concentrations of 1.11 mg/l at Imperial Dam. GS is currently monitoring quantity and quality of the discharge from the saline springs and studying the feasibility of salt control.

An exhaustive reconnaissance of Sinbad Valley was made in order to locate a suitable site for evaporation ponds. A fairly large area of relatively flat ground was needed. It would also simplify matters and reduce costs if a site were on public lands and close to the collector system. During the homesteading era, potential farmers selected the areas of flat land with deep soils for themselves, leaving the hilly, rocky lands in the public domain. No flat land could be found outside of the private lands in Sinbad Valley. The most favorable site is located just south of the mouth of the valley, close to the collector system. This site would reduce the length of the pipeline to a minimum. It could very well eliminate the need for lining of ponds. The soil is fine-textured alluvium and any seepage would be trapped by the barrier dam, to be pumped (recycled) back to the ponds through the pipeline.

Figure 3 shows one proposal for location of facilities needed to control salt using evaporation ponds. This procedure would require a collector system made up of a barrier dam, a sump, and a pumping plant. The

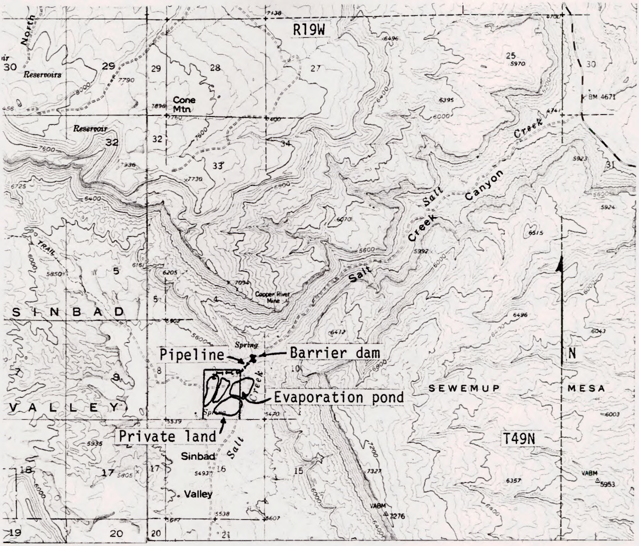


Figure 3. Proposed salinity control facilities for Salt Creek, southwestern Colorado.

collected water would be pumped a short distance up into the valley and evaporated in four ponds. Costs are estimated as follows:

Construction/Development and Replacement Costs

Collector system

Barrier dam	$ 20,000
Sump (gravel pack and perforated drain pipe)	10,000
Pumping plant	10,000
Amount to be set aside for periodic replacement of pump (assumes replacement at 5-year intervals). $10,000 X 2.44 (Sinking Fund Factor)	$ 24,400
High pressure, 4 inch, rigid PVC pipeline, 0.6 mile @ $60,000/mile	$ 36,000
Amount to be set aside for periodic replacement of pipeline (assume a 25-year life), $36,000 X 0.22 (Sinking Fund Factor)	$ 7,920
Evaporation pond (4) Protective dike - includes the cost to move earth from inside the pond area to the dike site, wet compaction and grade of dike fill material, and line the inside face of the dike with hypalon, see Day (1970) for specific guidelines.	
20 ft. high (32 cu. yd./ft) @ $48/running foot, plus hypalon liner (30 mil) on inside face of dike @ $20/running foot, 9,953 running feet of dike	$676,804
6 ft. high (4 cu. yd/ft) @ $6/running foot, plus hypalon liner @ $6.40/running foot, 5,359 running feet of dike.	$ 66,452
Construct 4.5 miles of single phase power line to the pumping site @ $10,000/mile	$ 45,000
Two phase converter	$ 1,600

Purchase of 120 acres of private land @ $600/acre	$ 72,000
BLM engineering and Design Costs	140,000
Land Appraisal	10,000
Preparation of Environmental Statement	328,000
BLM supervision of construction	18,000
Present value of total initial construction/development and replacement costs	$1,466,176

Annual Recurring Costs (Operation and Maintenance)

Electric power (53,243 KWH/year)	$ 2,460
Repair of pond dikes (including material)	10,000
Overhead and maintenance personnel costs	12,000
Total annual recurring costs	24,460

Present value of annual recurring costs (50-year project life):

$24,460 X 14.02 (buildup factor)	$ 342,929

Present Value of Total Costs (PVC)

PVC = $1,466,176 + $342,929 = $1,809,105

Present Value of Benefits (PVB)

PVB = 1.11 mg/l x $330,800 x 14.02 = $5,147,976

Benefit/Cost Ratio

$$B/C = \frac{PVB}{PVC} = \frac{\$5,147,976}{\$1,809,105} = 2.85:1$$

Net Project Benefits

PVB : $5,147,976
less PVC : $1,809,105
$3,338,871

If it is judged hazardous to the environment to leave the evaporation ponds unlined, the additional costs would be as follows:

Construction Costs

Pond liner of 20 mil PVC material (not buried),
80 acres or 387,200 sq. yds.

Cost to prepare pond bottom (grade site flat
and smooth, remove rocks, etc.),
\$.75/sq.yd. x 387,200 . . . . \$ 290,400

Cost to purchase and install liner,
\$2.00sq.yd. x 387,200 774,400

Present Value of Liner Costs

\$1,064,800

Present Value of Total Costs (PVC)

PVC = \$1,064,800 + \$1,809,105 = \$2,873,905

Present Value of Benefits (PVB)

\$5,147,976

Benefit/Cost Ratio

$$B/C = \frac{\$5,147,976}{\$2,873,905} = 1.79:1$$

Net Project Benefits

PVB: \$5,147,976
less PVC: \$2,873,905
\$2,274,071

2. Stinking Spring - Onion Creek

Onion Creek drains Fisher Valley and is tributary to the Colorado River. The mouth of the Creek is located 19 miles northeast of Moab, Utah. Base flow originates in the La Sal Mountains and is used for irrigation of hay fields in Fisher Valley. Base flow is approximately 2 cfs and salt concentration is 800 mg/l as the creek enters the "narrows" of Onion Creek Canyon. Stinking Spring discharges approximately 80 gpm into the Creek from two major points; one yields 57 gpm at a concentration of 18,980 mg/l, the other discharges 23 gpm at a concentration of 14,600 mg/l. These two combine to yield a total of 128 ac-ft. of water and 3,084 tons of

salt annually. Salinity of Onion Creek below Stinking Spring increases to 3,100 mg/l because of the high salt concentration of this spring water. If Stinking Spring water could be kept from entering the Colorado River, the salt concentration at Imperial Dam would be reduced by 0.24 mg/l.

Figure 4 shows the possible location of a control structure and collector to prevent saline spring water from entering Onion Creek and divert it into a pipeline, the pipeline location, and evaporation pond site. In this instance the pond would need to be lined to prevent seepage of brine through the sandy soil into the Colorado River. Day (1970) provides a good manual on procedures to be followed in constructing brine ponds and installing liners to reduce seepage. Costs of such a project are computed as follows:

Construction/Development and Replacement Costs

Collector system - Barrier dam and gravel sump	$ 20,000
3 inch, rigid PVC pipeline, 5 miles @ $60,000/mile	300,000
Air release valves	10,000
Amount set aside for periodic replacement of pipeline (assume a 25-year life) $310,000 x 0.22 (Sinking Fund Factor)	68,200
Evaporation Pond	
Protective dike 20 feet high and hypalon liner on inside face of dike, 3194 running feet of dike @ $68/ft.	217,192
Protective dike 6 feet high and hypalon liner on inside face of dike, 2614 running feet of dike @ $12.40/ft	32,414
Pond liner of 20 mil PVC material (not buried), 64 acres or 309,760 sq. yds.	

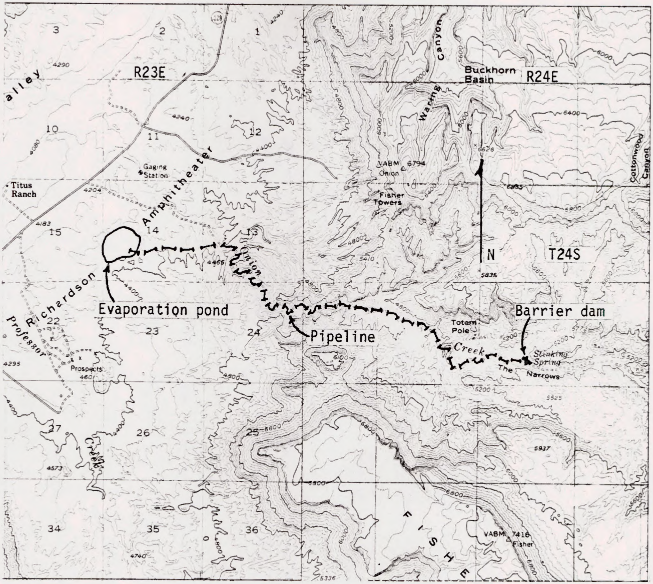


Figure 4. Proposed salinity control facilities for Stinking Spring located on Onion Creek, northeast of Moab, Utah.

Cost to prepare pond bottom (grade site flat and smooth, remove rocks, etc.) \$.75/sq.yd. x 309,760.	\$ 232,320
Cost to purchase and install liner \$2.00/sq.yd. x 309,760	619,520
BLM engineering and design costs	215,000
Preparation of environmental statement	500,000
BLM supervision of construction.	20,000
Present value of total initial construction/ development and replacement costs	\$ 2,234,646

Annual Recurring Costs (Operation and Maintenance)

Repair of pond dikes (including material)	\$ 5,000
Overhead and maintenance personnel costs.	8,000
Total annual recurring costs.	13,000
Present value of annual recurring costs (50-year project life): \$13,000 x 14.02	\$ 182,260

Present Value of Total Costs (PVC)

PVC = \$2,234,646 + \$182,260 = \$2,416,906

Present Value of Benefits (PVB)

PVB = 0.24 x \$330,800 x 14.02 = \$1,113,076

Benefit/Cost Ratio

$$B/C = \frac{PVB}{PVC} = \frac{\$1,113,076}{\$2,416,906} = 0.46:1$$

Net Project Benefits

PVB: \$1,113,076

less PVB: \$2,416,906

negative \$1,303,830

C. Summary

Control of salt yielded from point sources can be technically and economically feasible. The Bitter Creek well near Rock Springs, Wyoming

was successfully plugged with benefits far in excess of the costs, B/C ratio of 7.93 to 1. However, it should be pointed out that the financial and environmental risks involved in dealing with aquifers located at great depths and/or aquifers under pressure, can be high. The proposed control of salt in Salt Creek, Colorado using a system of evaporation ponds appears to be feasible. Even when the ponds are lined, a very expensive task. This is because of the extremely high salt concentrations in the water. A similar project proposed for Onion Creek, Utah is not economically feasible because of the lower concentration of salts in Stinking Spring. It is, however, still technically feasible.

IV. CONTROL OF SALINITY IN SURFACE RUNOFF

Salinity in surface runoff is directly related to content and availability of salt in soils and movement of soils by erosion. Salinity can be reduced through any activity which leads to increased infiltaration and reduced or controlled runoff. The major causes of soil disturbance and salinity are grazing by domestic livestock, feral horses and burros, and wildlife; recreation activities, including off-road vehicles (ORV); oil-gas and mineral exploration; mining claim assessment work; and development activities and final production of oil-gas wells, underground mines, and strip coal mines.

Control of salinity requires that uses by man be allowed only to the degree that they do not result in loss of soil. In the case of surface mining, where the soil and vegetation are completely destroyed, and highly saline or other toxic minerals are brought from great depths to the surface, mitigating measures will be needed. These should include retention dams to collect and hold toxic runoff, proper design of support facilities such as access or haul roads, and restoration of topsoil and vegetation to the site when mining operations are completed. When ORV use is allowed on saline, fragile soils, it should be recognized that it may cause irreversible harm to soils and vegetation. Control of salinity can be accomplished by confining ORVs to prescribed areas where runoff can be retained in reservoirs.

Effects on salinity of extensive uses, such as livestock grazing, can be reduced through proper application of accepted grazing management

principles. These include the allowance of grazing when soils and plants are least harmed by trampling or defoliation (proper season of use), control of livestock numbers to reduce harmful impacts, rotation of grazing and rest treatments to increase vegetative cover, and total exclusion of grazing where necessary. Key elements to be considered when prescribing grazing treatments are soil and vegetation factors as they relate to reduction of salt concentration in surface runoff. Treatments prescribed may be different from those designed when maximization of livestock benefits is desired.

BLM (1978) described general characteristics of grazing treatments that should be prescribed for three classes of saline lands, i.e., highly, moderately, and slightly-nonsaline. No changes are suggested for treatments applied to moderately and slightly-nonsaline lands. To reiterate - management objectives on moderately saline lands should include the increase in ground cover, litter, and improvement in soil tilth in order to increase infiltration and reduce saline runoff. The rangeland should be maintained in good to excellent condition. The grazing treatment should provide moderate utilization of forage (40 percent). The rest cycle should be long enough for soils to recover from the effects of trampling (compaction) through frost-heaving. This period varies with soil texture. In no case should this period be less than the time needed for seedling establishment.

Grazing management for salinity control on slightly-nonsaline lands would have the objective of maintaining only sufficient vegetation cover to reduce erosion while still allowing the greatest amount of runoff without soil degradation. This would require heavier than moderate grazing within a grazing management formula. Range condition should be maintained in at least a good category. However, the resulting loss of water to the upland site may well cause a reduction in livestock and wildlife forage, below optimum desired production.

The 1977 salinity status report (   ) suggested that removal of livestock from the highly saline lands could be an effective means of controlling salinity. These lands are often characterized by unstable soils and sparse vegetation. Soils may be fine-textured and relatively high in sodium. They are easily compacted by trampling under these conditions - resulting in low infiltration, high runoff, increased salinity, and low levels of effective soil moisture. It is still felt that removal of livestock offers the greatest level of salt reduction in surface runoff, especially on sites supporting less than 15 percent ground cover of perennial plants. On these sites, soil characteristics have a greater influence over infiltration than vegetation, because of the large areas of bare ground and low percent litter. Frost-heaving or shrink-swell can change a hard packed soil into a fluffy, friable soil surface, greatly increasing infiltration. Grazing destroys this friable soil condition.

On areas where ground cover of perennial plants is sufficient to support grazing animals, grazing may be tolerated when soils are frozen ( ). The use should allow sufficient rest from grazing at a time when the freeze-thaw cycle will improve soil tilth through frost-heaving. The grazing period reported on by Lusby (1978) is November 15 through February 15. Figure 5 illustrates the effect upon a loose, friable soil when sheep were allowed to graze during the critical spring period (through March 31), when soils were moist and unfrozen. Forage utilization should not exceed 50 percent on grazed pastures ( ). If utilization of forage is no more than 50 percent, a reserve of forage will be created for watershed protection and use during drought years. Grazing use should be rotated, to rest plants from continuous winter defoliation.

Table 1 shows the result of two treatments on reducing salinity in surface runoff from highly saline lands in the Upper Basin states of Colorado, Utah, and Wyoming.

Errata to 1977 Salinity Status Report

Appendix XII-1 of the 1977 Salinity Status Report ( ) discusses the elimination of areas from grazing that are unsuitable for that purpose. These areas are usually too steep, rocky, lack sufficient forage, or covered with dense trees. In the Soldier Creek allotment

Figure 5. Deep hoof prints made by sheep grazing on a moist, unfrozen, clay loam soil.

Table 1. Economic Impact of a Winter Grazing System and Livestock Removal on Salinity from Highly Saline Lands in the Upper Colorado River Basin.

Treatment Practice	Water Retained Acre-Ft.	Sediment Reduced Tons/yr	Salt Reduced Tons/yr	Salt Concentration Change mg/liter/yr	Forage Reduced AUMs/yr	Present Value Benefits $1,000	Present Value Costs $1,000	Net Benefits $1,000	Benefit Cost Ratio
Winter Grazing (3 million acres)	10,985	2,221,738	80,493	-6.21	45,300	49,370	22,450	+26,920	2.20:1
Livestock Removal* (3 million acres)	12,206	2,468,598	89,437	-6.86	95,024	54,700	11,800	+42,900	4.63:1

* Taken from Table VII-2, BLM(   ).

example, 60 percent of the juniper-pinyon vegetative type was listed as being usable. The grazing capacity was eliminated from the other 40 percent, leaving use on 6,907 of the 11,512 acres. In computing the results of grazing management or removal of livestock as treatments for controlling salinity, no benefits should have been ascribed to the unused acreage. However, this reduction was not made, resulting in a too high estimate of benefits of the two grazing treatments.

The error made on the Soldier Creek allotment is significant (11 percent), however, when combined with the other two sample allotments and extrapolated to all highly saline lands in the Upper Basin, the error is a nonsignificant 1 percent. Therefore, the data on benefits in the 1977 salinity status report will not be changed. Care should be taken in computing salinity benefits, to remember to deduct effects on unusable areas.